Effect of Crop Rotations on Soil Moisture Levels

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On the Dark Brown Soils of Northwestern Saskatchewan, a three-year rotation of; fallow - crop - crop is typically followed, although rotations used vary from fallow - crop to continuous cropping. As more attention is focused on the problems of soil salinity (estimated to affect 10% of our available acreage) and declining soil organic matter (estimated to have declined 40% over the past 60 yr.) more producers are moving to extended rotations. Producers are also expressing greater interest in more frequent use of green manure or forage crops in grain crop rotations. Yields in crop rotation studies conducted in the past were traditionally related to factors such as weed populations, soil fertility and crop incompatability. Less attention has been focused on the effects of crop rotations on soil moisture levels and crop utilization of soil moisture.

When rotations are extended, all cropping inputs become crucial; more soil nutrients are removed with the crop; weed control is more difficult since summerfallowing is practiced less frequently; insect and disease problems may become more severe due to frequent cropping to susceptible crops or alternate hosts. Farmers have at their disposal a variety of inputs and management tools that can be used to help overcome these problems; commercial fertilizers, herbicides, seed protectants, fugicides and insecticides. Crop rotation can be used to provide nitrogen, by using legume crops having nitrogen fixing rhizobia associated with their roots. Crop rotation can also be used in pest control. Weed control can be facilitated by selection of crops for which good chemical controls are available. In this manner, weed populations can be reduced to allow cropping to a crop for which chemical controls are less effective. By rotation of susceptible crops with non susceptible ones, varying degrees of insect and disease control can be obtained.

The quantity of moisture received is one factor over which we have little control. Agronomists have examined a number of ways in which this resource can be managed after it is received. Cultural practices have been developed to increase snow trapping on stubble fields, to improve efficiency of moisture storage during summerfallowing and to conserve moisture in the seed placement zone prior to and following spring seeding. A more complete understanding of how different crops and summerfallowing frequency affect soil moisture levels and moisture utilization would add another management tool that producers could use, particularly in extended rotations.

This paper is based on a long-term crop rotation study intiated by C.H. Keys conducted at the Experimental Farm, Scott, Sask. While the study is limited by the number of crops and rotations used, it does provide information on some of the major crops and rotations used in the area and hopefully will provide a base for additional research.

The test was conducted on a Dark-Brown Elstow Clay Loam Soil. Plot sizes were approximately 7 m by 30 m and treatments were replicated four times. Soil moisture determinations were made gravimetrically on soil cores taken to a depth of 90 cm. Sampling was done as near to seeding as possible in the spring and shortly after harvest in the fall. Rotations used are shown in Table 1. During the period 1966 to 1971 wheat was used as the crop grown on summerfallow. In 1972 and in subsequent years, rapeseed was grown in place of wheat on fallow in all rotations except where summerfallow substitutes were used. In 1980 the rotations were changed again to facilitate more direct comparisons between wheat and rapeseed when grown on summerfallow.

During the period 1966-71 an average of 223 mm of precipitation was received between the spring and fall soil samplings, during 1972-79 average growing season precipitation was 199 mm.

Table 1. Crop Rotations - Scott, Sask.

Rotation	Crops 1966-71	Crops 1972-79
I	continuous wheat	continuous wheat
II	fallow - wheat	fallow - wheat
III	fallow-wheat-wheat	fallow-rapeseed-wheat
IV	fallow-wheat-oats	fallow-rapeseed-oats
V	fallow-wheat-oats(alfalfa)-hay & break	fallow-rapeseed-oats (alf)-hay & break
VI	fallow-wheat-wheat-oats (alf)-hay-hay & break	fallow-rapeseed-wheat-oats (alf)-hay-hay & break
VII	fallow with wheat in rows-wheat	fallow with wheat in rows-wheat
VIII	fallow with oats in rows-wheat	fallow with oats in rows-wheat
IX	fallow with corn in rows-wheat	fallow with corn in rows-wheat
X	fallow with sunflowers in rows-wheat	fallow with sunflowers in rows-wheat

Moisture use by Crops

Wheat grown on summerfallow during the 1966-71 period had the highest soil moisture use, ranging from 105 to 125 mm (Table 2). This would be expected since more soil moisture was available to the crop grown on summerfallow. Where wheat was grown following the summerfallow substitutes, moisture use was similar to wheat grown following conventional summerfallow.

Wheat grown on stubble used less water than wheat grown on fallow, but more than oats grown on stubble. Water use by continuous wheat was lower than for stubble grown wheat.

Polish type rapeseed (*Brassica compestris*) grown on summerfallow during 1972-79 used significantly less water than did wheat following a summerfallow substitute. Rapeseed used only slighly more water than did wheat grown on stubble. It is apparent that Polish type rapeseed is not as heavy a water user as is wheat. Some of this difference may be attributed to the reduced number of days required for the rapeseed crop to reach maturity. However, rainfall between maturity of the rapeseed crop and wheat was not sufficient to account for more than one third of the difference.

Table 2 Soil Moisture Availability and Use - Scott Rotations 1966-71.

	Soil moisture in m.m.		
	available in spring	used	left
Continuous wheat	95	58	37
Summerfallow			
Wheat	163	124	39
Summerfallow			
Wheat	154	111	43
Wheat	108	70	38
Summerfallow			
Wheat	164	125	39
Oats	100	50	50
Summerfallow			
Wheat	162	121	41
Oats (alfalfa)	109	60	49
Alfalfa hay	104	34	70
Summerfallow			
Wheat	142	105	37
Wheat	112	74	38
Oats (alfalfa)	111	64	47
Alfalfa hay	102	49	53
Alfalfa hay	93	61	32
Wheat in rows			
Wheat	169	132	37
Corn in rows			
Wheat	157	123	34

Table 3 Soil Moisture Availability and Use Scott Rotation 1972-79.

	Soil moisture in m .m.		
	available in spring	used	left
Continuous wheat	101	62	39
Summerfallow			
Rapeseed	162	101	61
Summerfallow			
Rapeseed	150	90	60
Wheat	113	74	39
Summerfallow			
Rapeseed	161	94	67
Oats	118	65	53
Summerfallow			
Rapeseed	142	69	73
Oats (alfalfa)	117	76	41
Alfalfa hay	119	60	59
Summerfallow			
Rapeseed	112	62	50
Wheat	115	85	30
Oats (alfalfa	93	67	26
Alfalfa hay	94	63	31
Alfalfa hay	93	53	40
Wheat in rows			
Wheat	139	101	38
Corn in rows			
Wheat	156	126	30

The quantities of soil moisture remaining after harvest were related primarily to the crop grown. Wheat consistently resulted in lower levels of soil moisture than did oats or rapeseed. Wheat grown continuously resulted in similar levels of soil moisture after harvest to those where wheat was grown in shorter rotations. The higher levels of soil moisture remaining following rapeseed would increase the amount available to a succeeding crop however where a rapeseed-fallow rotation is followed, this moisture could contribute to seepage resulting in soil salinity.

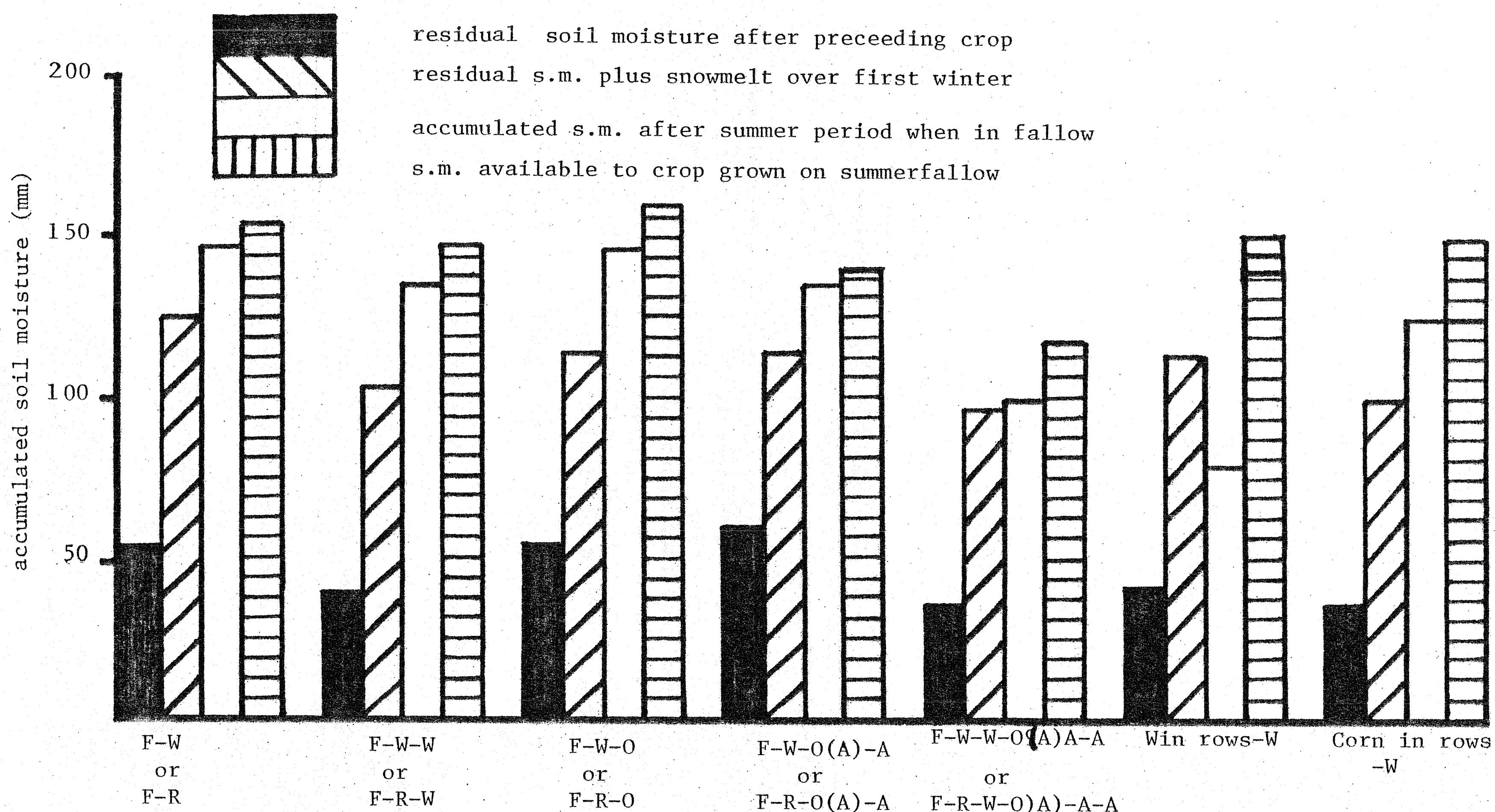
Soil moisture levels in the fall, following the hay crops in the 4 to 6-year rotations were at or above levels following wheat. In the hay rotations some soil moisture recovery could have occurred following breaking, which was usually done in July after hay removal. In the 4-year rotation, soil moisture levels had risen to 59 to 70 mm in the fall, where as in the 6-year rotation soil moisture was only 32 - 40 mm after breaking. One factor which is not accounted for is the depletion of soil moisture below the 90 cm sampling depth by the hay crop. It is well documented that alfalfa roots will penetrate below this depth, particularly where the crop becomes well established such as in the six-year rotation.

Soil moisture storage in summerfallow

Soil moisture storage during the fallow period followed similar trends during both periods, 1966-71 and 1972-79, for all rotations except rotations II and VI. The combined data for these two periods are presented in Figure 1. Most of the soil moisture storage in fallow occurred from snowmelt overwinter following the preceeding crop. The quantities stored over the first winter period did not vary greatly between rotations, and the differences were not statistically significant. Storage during the summer period was quite variable and the differences were statistically significant (Figure 1). In the conventional grain crop rotations, storage was 20 - 30 mm. In the mixed grain - forage rotations, 20 mm was stored during this period in the 4-year rotation and only 5 mm in the 6-year rotation. In the 4-year rotation the alfalfa did not become well established and was readily eradicated during summerfallowing. However, in the 6-year rotation the alfalfa was established better and persisted throughout much of the fallow period and reduced moisture storage. Where wheat or oats were grown in widely spaced rows as summerfallow substitutes, there was a loss of soil moisture during the summer period. Corn or sunflowers grown in widely spaced rows resulted in near normal moisture storage during the summer period.

Storage of snowmelt moisture over the final winter period was highest where wheat or oats in rows were used in summerfallow substitutes, with the corn or sunflowers in rows resulting in lower snowmelt storage. The lowest total fallow moisture storage was recorded on the four and six-year rotations. When combined with the low residual moisture prior to summerfallowing in the six-year rotation, there was a significantly lower quantity of moisture available to the crop grown on summerfallow in this rotation.

Figure 1 Accumulation of Available Soil Moisture in Summerfallow



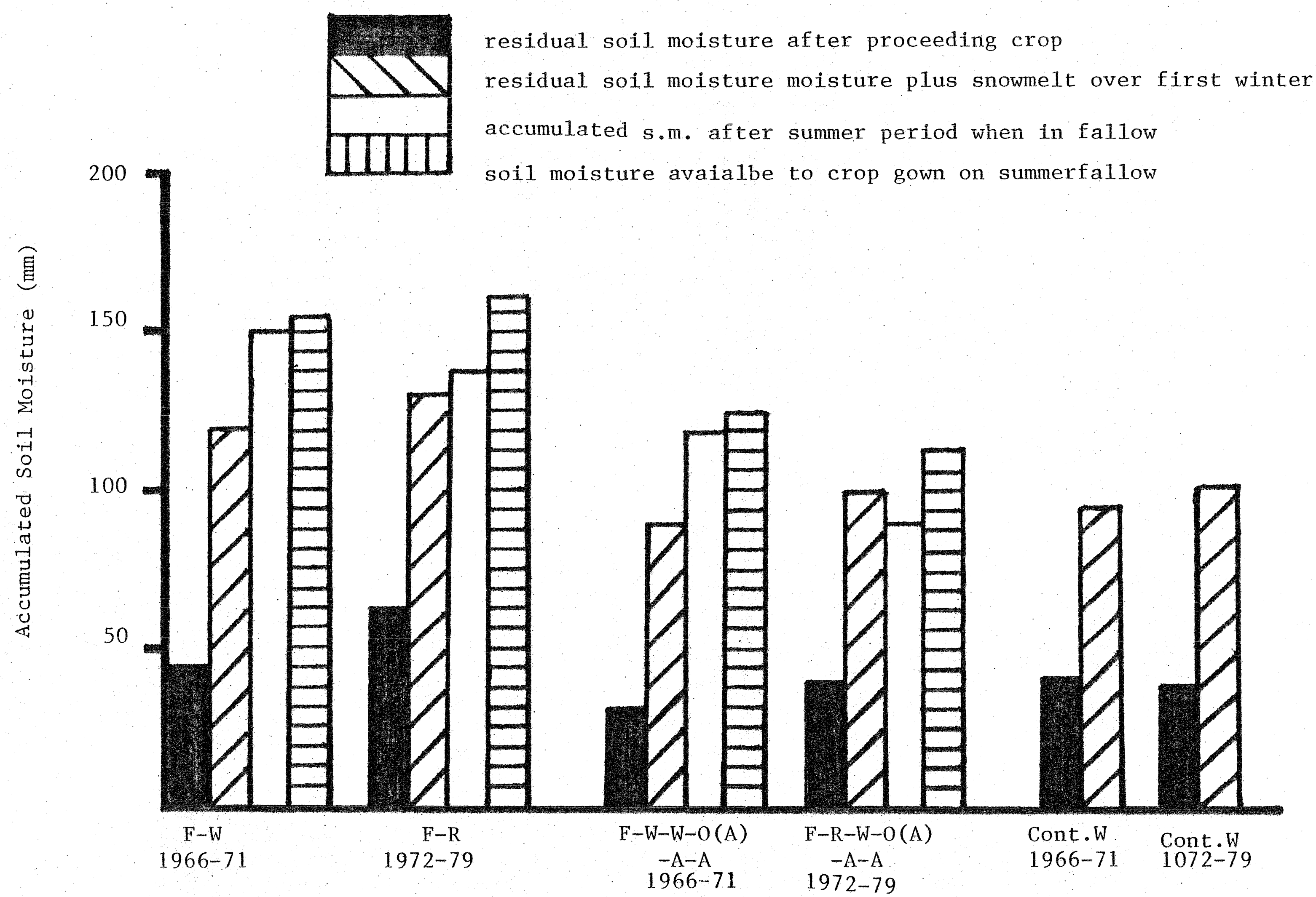
The two rotations in which notable changes occurred between the two time periods were the fallow-wheat which was changed to a fallow-rapeseed rotation and the 6-year grain-forage rotation.

At the start of the fallow period, residual soil moisture from the preceeding crop was higher in the fallow-rapeseed rotation than when the rotation was fallow-wheat (figure 2). In turn, soil moisture levels the following spring were higher for this rotation. During the summer period however, more moisture was stored in the fallow-wheat rotation. This difference in storage may be partly due to differences in trash cover. The trash from the rapeseed crops disappeared rapidly in summerfallow, while wheat residues persisted longer and may have reduced surface evaporation. Another possible explanation is that the higher levels of soil moisture occurring early in the fallow period contributed to greater losses below the sampling depth. If such were the case, fallowing after a rapeseed crop would likely contribute more moisture to subsoil seepage and consequently greater salinity. Soil moisture gained from snowmelt over the final winter period was higher in the fallow-rapeseed rotation than the fallow-wheat rotation, resulting in a slightly higher level of available soil moisture at the time of seeding.

In the six-year rotation soil moisture accumulation during the summer period when in fallow was markedly lower during the period 1972-79 than in the earlier period. During the period 1966-71 less persistent varieties of alfalfa were used and generally less vigorous stands were obtained. Thus, during the earlier period the alfalfa was more readily eradicated during fallow, where as it was more persistent in later years contributing to greater losses of soil moisture during the fallow period.

Soil moisture levels from the continuous wheat rotation are included in figure 2, as a reference point. The levels of soil moisture in this rotation changed very little during the two time periods.

Figure 2 Accumulation of Avilable Soil Moisture in Summerfallow



Relationship between soil moisture levels and crop yields

In this study crop yields tended to be related to levels of soil moisture at the time of seeding although other factors such as soil fertility and weed populations also affected yields. Yields of wheat grown on fallow were similar for rotations II, IV and V as were levels of available soil moisture at the time of seeding (Table 4). Soil moisture levels were lower on rotations III and VI and wheat yields also tended to be lower. Wheat yields on stubble also tended to decline with declining levels of soil moisture at seeding. Yields of rapeseed did not fallow this pattern as closely. Rapeseed yields in the straight grain rotations decreased as avaialbe soil moisture levels decreased. However, in the grain-forage rotations, yields tended to be higher per m.m. of available soil moisture at seeding.

Summary

Although alfalfa may be useful in improving levels of soil organic matter and supplying nitrogen to succeeding crops, the lower soil moisture levels that occur on Dark Brown Soils as a result of this practice, restricted yields of succeeding crops. Where the alfalfa became well established and persisted during the fallow year, soil moisture levels on fallow were particularly low. Studies conducted on Black and Gray Luvisolic soils in the Melfort and Loon Lake areas have shown that on those soils, forage crops do not necessarily result in lower soil moisture levels. In some cases storage of moisture has been enhanced in grain-forage rotations.

Crops such as rapeseed which do not use as much of the available soil moisture as wheat are better adapted to production on fallow, as they result in higher moisture levels for succeeding crops in this area. Such crops are not adapted to a crop-fallow rotation because the higher moisture levels in the fallow period could increase saline seepage.

In a wheat monoculture system there is a sharp decline in the amount of soil moisture available to the first stubble crop as compared with a fallow crop (Figure 3). As recropping is extended to a second stubble crop and to continuous wheat, available moisture at seeding declines only slightly. It would appear that sufficient moisture is available to continuous wheat to maintain yields at levels near those obtained on first crop stubble.

Crops grown in widely spaced rows as summerfallow substitutes do not result in higher levels of moisture available to the succeeding crop as compared with conventional summerfallow, at least on medium textured soils. On light textured soils where moisture storage efficiency in fallow is very low or where erosion of fallowed fields is a problem, this practice may have some merit. This practice may also be beneficial in improving moisture storage following a forage or green manure crop.

Table 4 Crop Yields and Available Soil Moisture at Seeding

Rotation	W - on fallow	W - on stubble
I Cont. W		1890 (95)
II F - W	2731 (163)	
III F - W - W	2498 (154)	2103 (108)
IV F - W - O	2640 (164)	
V F - W - O - A	2623 (162)	
VI F-W-W-O-A-A	2452 (142)	2243 (112)
I Cont. W		1252 (101)
II F - R	1031 (162)	
III F - R - W	869 (150)	1736 (113)
IV F - R - O	953 (161	
V F - R - O - A	914 (142)	
VI F-R-W-O-A-A	897 (112)	1898 (115)

Yields are in kg/ha with available moisture in mm in brackets.

Figure 3 Effect of Extended cropping on Soil Moisture Levels